THE PRINCIPLES OF BOTANY,

AS EXEMPLIFIED IN THE

CRYPTOGAMIA.

FOR THE USE OF SCHOOLS AND COLLEGES.

BY

HARLAND COULTAS.

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TO

T. S. ARTHUR, Esq.,

AS

A TRIBUTE OF ESTEEM FOR HIS TALENTS AND VIRTUES,

This Little Book

IS

RESPECTFULLY DEDICATED,

BY

THE AUTHOR.

INTRODUCTION.

THERE is no department of natural history which is more important, beautiful, and interesting than Botany, or the natural history of plants. Let us take, not a costly exotic from the conservatory, but any common wild flower or weed. What exquisite symmetry and elegance of form! The choicest works of art, the most finished productions of genius, are but as the poor efforts of savages when contrasted with this wonderful work of nature! We know that this humble flower grows when fanned by winds, watered by rains, warmed by the sun, and that it must derive some portion of its substance from the soil. But how does Nature form this green leaf and this beautiful blossom? We see her constantly engaged in building up these living forms, and weaving the air, the earth, and the water into every imaginable variety of vegetable fabric. The whole earth is, in fact, one vast chemical laboratory or workshop, where Nature is ever operating with an untiring industry in fabricating living forms out of lifeless inorganic matter. Let us endeavor to trace the movements of this glorious mechanism framed by the hand of the Almighty; let us "consider the lilies of the field, *how* they grow."

And let it not be assumed, at the outset of this investigation, that the intelligence of man is incapable of searching out

the mysteries of vegetation. Before the time of Newton, there were many men who had seen apples fall to the ground without ever reflecting on the cause of their fall. Newton saw the same, and thought. The result of his reflections was the production of his immortal work, the *Principia*, and the development of the theory of gravitation. He showed with what small means Nature attains the most magnificent results. It was the mutual attraction subsisting between the earth and apple that brought the apple to the earth's surface; and the same mutual attraction retains the moon and planets in their orbits, causing them to sweep out in immensity those sublime curves with which the mind of the geometer is familiarized. It is by the attraction of other suns that our own sun, or rather star, is upheld in space; whilst all the stars that sparkle on the roof of night, and whose light comes to us from the most distant regions of the universe, are upheld by mutual attraction. Such was the sublime discovery of the illustrious Newton. What though the means which Nature employs in the construction of the various forms of plants is at present only imperfectly understood—if the law that regulates the motion of masses of matter has been discovered, why not the law which governs the motion of atoms of matter, and causes them to collect around every germinating seed or growing plantlet, so as to develop it with such unchanging constancy and regularity into the same definite form of life and beauty? Man is not destined to continue forever hopeless and helpless amidst the forces of nature. It is his prerogative "to subdue the earth," and "have dominion."

The law of material attraction may be thus expressed: Mat-

ter may attract matter at all distances from zero to infinity. This attraction takes place with a force varying directly in proportion to its quantity, and inversely as the square of the distance. Now when matter collects into masses, as we see it has done in the case of the starry heavens and planetary bodies, two or more bodies, thus mutually attracting each other, separate sometimes to distances all but infinite, but according to a fixed and determinate mathematical law, the distance being in exact proportion to the ratio of their respective magnitudes and quantities of matter. We call the name of this species of attraction, *gravity*. But when matter retains its elementary condition, and exists in the form of those invisible particles called atoms, two or more mutually attracting particles must be brought by the same law infinitely near to each other before they can exercise any mutual influence; and we give the name of *chemical affinity* to this kind of attraction.

To apply this philosophy to plants. They are the result, principally, of the atomic or chemical affinity, *combined with other agents*, and are a beautiful pile of matter borrowed from the atoms in the earth and air, and united together by the operation of natural laws for a little space of time. Fabricated by nature as material for the building up of higher organic forms, they perform their part in the ever-shifting scenery of life, and either become incorporated as food into animal bodies, or else, retaining their state as plants, they are the instruments used by nature to extract fertilizing principles from every falling shower and passing breeze, which they impart to the soil on which they finally decay. The end of

being accomplished, their beautiful and evanescent forms decay, they become disorganized, the pile of matter falls, and is restored by the operation of the common laws of chemical attraction to the earth and air from which it was taken.

We are accustomed to admire the magnificent spectacle of the starry heavens; but let us look on the earth, at the splendors of the vegetable creation. From the lowly Moss which raises its little sporangia hardly an inch above the ground, and covers with its minute, but exquisitely beautiful foliage, the rugged rocks and the bark of trees, to the noble arborescent Ferns of the tropics, from whose lofty summit a magnificent bouquet of gigantic fronds is gracefully pendent; from the little inconspicuous aquatic plant, called the Duckmeat, which covers the surface of the pools and stagnant waters with its scumlike vegetation, to the splendid Victoria Regia, the queen of water-lilies, cradled in the rolling billows of the mighty Amazon—what differences in size! what an advance in organic development! Yet nature has every intermediate variety of organization, passing, as we shall presently show, from the utmost simplicity to the sublimest grandeur of vegetable structure, through a beautiful and highly instructive series of transition-forms.

The forms of life called Plants deserve every attention. Botany is not a mere accomplishment, but an important branch of education. If it be true, as some philosophers have asserted, that the whole chain of organic being, from man down to the humble spire of grass, is only a manifestation of life in different degrees of development, then are we all personally interested in this inquiry. It is in plants that mineral

matter first becomes endowed with life. It is there that we meet with its earliest, humblest indications. We know that every plant is formed out of the mineral matter of the earth and atmosphere, and that the vegetable world is formed out of mineral matter for the support of animal life. Thus the plant connects the animal with the mineral. He who would successfully study the laws of life as developed in the animal world certainly ought not to neglect the investigation of plants on which animals depend for food, or rather for their very existence.

It must be clear, to reflecting minds, that plants and animals exercise a great many of the functions of life in common. Both are nourished by food and air, are subjected to disease, decay, and death, and have the power of self-reproduction, or of continuing their species. Plants appear to be subject to similar organic laws to animals, in the development of their tissues, and the life in them is probably only a modification of the same universal principle of action which pervades all organic being. In the prosecution of physiological researches, it is therefore of the utmost importance that we should become conversant with the phenomena of vegetable vitality. In the development of living nature, there is too evident a system of dependency, and no link in the great chain of being can be dispensed with. Human physiology will progress, and the noble art of healing be better understood, in proportion as we understand the expression of life in inferior organic forms. If we would understand the higher manifestations of life in ourselves, we must neglect the study of nothing that has life,

however humble may be its manifestations of vitality or simple its organic structure.

And let me suggest that the study of the simple plants ought to take the precedence of those whose organization is more complex and intricate, as being the simplest expression of the laws of vegetable life. It is now certain that the growth of plants, and, in fact, of every organic being, is the result of the operation of certain fixed and immutable laws. All who have noticed the phenomena of the life of plants must be satisfied that this is the case. Thus, all have a period of life assigned them, more or less limited, during which we see them, as it were, by successive increments, slowly elaborated out of the earth and atmosphere, arrive at the full perfection of their growth and beauty, reproduce themselves, and then die. The period of time during which these phenomena take place varies according to the peculiar structure of each plant. Thus plants, whose structure is very simple, as ferns, mosses, and many of our flowering-plants, grow, reproduce themselves, and then die, and this all in a single season. In other instances, where the organization is higher, the duration of life is much longer. But the forest-tree, lifting its massive stem for centuries to the light of day, has also an appointed period to its life, as regular as the lowly moss that grows beneath its shade. A few months, however, suffice to perfect the one, and many centuries are required by nature before she can build up the other. Now it is evident that the growth of the humble moss is only a simpler expression of that same law which operates in the production of the forest-tree; and if we can explain the law of development in the one case, we can in the other.

The science of Botany has not yet received that attention to which it is justly entitled, on account of that forbidding array of dark technicalities which has been but too frequently presented to the minds of those seeking instruction. But much pleasing, wonderful, and instructive truth may be communicated about plants in plain ordinary language, and by thus studiously avoiding the use of scientific terms, and keeping to the simplicity of nature, the approach of the student to the study of them may be greatly facilitated. Linnæus and his scholars have generally written in Latin. They addressed themselves to anatomists, physicians, and philosophers, and not to the people, or they would have adopted a different language as a means of communicating thought. I shall endeavor to copy Nature in her simplicity, and to conduct my readers, by a plain and easy pathway, to the noble temple of Flora; and, when they shall catch a glimpse of the glorious interior, of the play of those magnificent laws of life of which man is the highest expression, and which operate in the production of the vast chain of organic being beneath him, there is no difficulty which they will not attempt to surmount, in order to learn more about those beautiful forms of life called plants, and to solve the problem of their growth and reproduction.

PART I.

ON THE

SIMPLE ELEMENTARY ORGANS OF PLANTS.

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1. When the structure of plants is examined, parts of that structure are found to have peculiar functions assigned them; these parts are called organs, and the structure is said to be organized. The lower tribes of plants possess fewer separate organs, and the functions exercised are more general and less restricted than in the higher tribes of plants in which the organs are more numerous and complicated. The organization of a plant is considered to be complex or simple, highly developed or the contrary, just in proportion to the number of distinct organs of which it is composed, and of separate and peculiar functions exercised by its tissues.

2. The organization of plants, when examined with the microscope, is seen to consist of a united mass of cells or vesicles, tubes, and fibres. These cells, tubes, and fibres, which in some of the lower forms of vegetation are developed as separate and independent plants, gradually unite together as organization advances in complexity of structure, and constitute the substance of the more highly organized plants.

3. The cells, tubes, and fibres, thus associated, constitute what botanists call the cellular, vascular, and woody tissues of plants. The first is of universal occurrence; the other two kinds of tissue are only partially introduced or wholly absent from the structure of a great many plants, such as mosses and seaweed, which consist of cellular tissue alone.

4. That all the parts of plants are fabricated out of cells is evident from the fact that the cellular nature of the vegetable substance *invariably* manifests itself when sections of that substance are examined by means of transmitted light under the microscope; the growth or extension of the parts of plants must therefore be the result of the development of new cells, and the size and form of plants must depend on the number and nature of the arrangement of the new cells thus developed. It is therefore proper to begin these investigations by first considering the cells or simple elementary organs of plants separately, and their mode of development into the different tissues; we may then study more profitably the tissues as combined together in the form of root, stem, and leaves, which have been very properly termed the compound organs of plants. We shall first show that all the different forms of tissue are only modifications of the cellular, and that they all originate in the simple cell as a point of departure.

CHAPTER I.

CELLULAR TISSUE.

5. THIS consists of a number of vesicles or bladders, with thin transparent sides adhering together, and containing fluid. A piece of honey-comb gives a very good idea of this tissue when it is at all regular, which is seldom the case, the walls of the cells in the honey-comb representing the sides of the cells in plants, and the inclosed spaces the cavities formed by the union of the cells themselves. To become familiar with this tissue, it is only necessary to examine a thin slice of any of the succulent plants with the microscope, or the pulpy part of an orange, where these cells may be readily distinguished by the naked eye, and separated from the mass of the fruit. When the body is sufficiently transparent, its internal structure may be perceived with the aid of the microscope, without examining it in section. We may sometimes see this cellular structure very distinctly in a piece of thin transparent sea-weed, or "in a young and delicate rootlet," and "observe the closed cavities entirely circumscribed by nearly transparent membranous walls."*

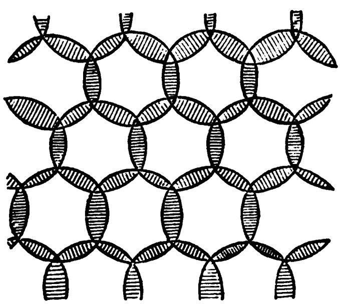
6. Each cell is in itself a distinct and separate cavity; the wall or partition between two cells is therefore double, being

* Gray's Botanical Text-Book.

produced by the cohesion of their sides. The double nature of the cell-wall may be readily detected by boiling the tissue for a short time, when the cells will separate. In ripe pulpy fruits, the cells may be separately picked out, and examined without boiling. Hence, when pulpy fruits are cut into pieces, there is very little flow of fluid from them, the juices of the fruits being retained in the little membranaceous sacs or cells of which the pieces are composed.

7. The primitive or typical form of the cells is supposed to be spherical or globular (Fig. 1), and this form the cells

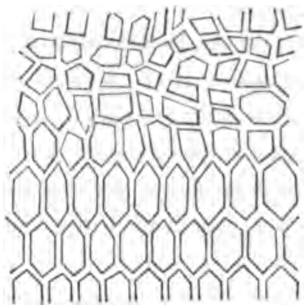
Fig. 1.



retain in the lax tissues of succulent plants, in the pulpy parts of fruits, where they do not impress each other, and where growth takes place equally in all directions. But when any part of the plant grows more rapidly in one direction than in another, the cells commonly elongate in that direction, and become elliptical, oblong, or even tubular if free from all adjacent pressure, and prismatic if laterally compressed, as is the case in young shoots and branches. In the pith and in the

parenchyma or green stratum of vegetable matter in the leaf, where the cells are globular by mutual compression, they assume an hexagonal or honey-comb like structure (Fig. 2).

Fig. 2.



The form of the cells, therefore, depends entirely on the circumstances in which they are placed, varying greatly in different parts of the same plant, their form being modified by the growth and peculiar functions exercised by the organs of the plant.

8. In the simpler tribes of plants, such as mosses and algæ, the cells depart but slightly from their primitive form, which they retain throughout the entire life of the plant. But in the more highly organized and complex plants, although the mass of the plant at first consists wholly of cellular tissue, yet as soon as the embryo plant begins to germinate, even whilst the cotyledons or first pair of leaves are yet developing above the earth's surface, certain cells are seen rapidly to depart from their primitive form, and to assume an elongated or tubular appearance; the septa, or walls, or partitions between

contiguous cells are wholly absorbed in the process of growth, and woody fibre and vascular tissue enter into composition. It will be easy to perceive, from these facts, how, from so simple an element as a cell, may proceed a countless number of different forms of tissue.

9. The substance out of which the cells of plants are formed is called Cellulose, which is of universal occurrence in all plants. This cellulose is formed out of a viscid mucilaginous fluid termed by vegetable physiologists cambium, or organizable matter, which fluid always precedes the appearance of the cells, and is ever present when vegetable matter is in a state of growth.

10. A stratum of cambium appears in the young and vitally active tissues of plants in the spring of the year, and renders the bark so easily separable from the stem of plants at this season; this fluid matter is gradually organized into cells, and by the addition of these to their previously developed tissue, the growth of the plant is effected. In autumn, this cambium, or fluid matter, gradually disappears, the cells cease to form, and the parts of plants to elongate and enlarge, and the bark and stem again become firmly adherent.

11. True cellulose is always excessively thin and plastic when first developed, so as to be easily impressible into any form whatever. To this first layer of cellulose the well-contrived term Protoplasm (πρῶτος first, and πλασμα formative matter), first proposed by Professor Mohl, is now applied. The thickness and rigidity afterwards acquired by cellulose are owing to the internal deposition of layers of incrusting matter which

has received the name of Lignine (*lignum*, wood), or sclerogen (σκληρὸς hard, and γεννάειν to generate).

12. In the lax parenchyma or tissue of plants, where the cells retain in part their spherical or cylindrical figure, in proportion as they retain that figure when they mutually impress each other do they necessarily touch each other at certain points only, leaving vacant spaces formed between the cells; which, when they occur as separate cavities, are called intercellular spaces; but when they follow the course of the tissue, and occur as continuous and tubular sinuosities, they are termed intercellular passages.

13. Sometimes these intercellular spaces become the receptacles of the peculiar secretions of the plant. The transparent dots seen in the leaves of the orange, the myrtle, and the St. John's-wort, when they are held up to the light, are produced by the presence of oil in the intercellular spaces of the parenchyma, whilst the transudation of the milky secretions into the intercellular passages forms the so-called vessels of the latex.

14. These consist of long, irregularly-branching, and anastomosing tubes, of extreme tenuity and transparency, having a diameter of about 1-1400th of an inch, and forming, by their union, an anastomosis or network, like the veins of animals. They are visible only under a powerful microscope, and were formerly thought to be cells united in a linear series, their septa being obliterated; but, at a very early period, the milky secretions of the plant may be seen circulating through the intercellular passages, and from these secretions the membrane forming the continuous and anasto-

mosing tubes of the latex is ultimately developed. The secretion of the latex may be readily seen in dandelion, euphorbia, or celandine, by breaking any leaf or shoot of these plants.

15. Besides the intercellular spaces and passages already described, other cavities exist in the parenchyma or cellular tissue, which are usually filled with air, and are called lacunæ or air-cells. In aquatic plants large lacunæ or air-cells are formed in the parenchyma of the stem and leaves, by the rupture or absorption of the septa between a number of contiguous cells. These lacunæ, in the pond-weeds, assume a regular form, which is constant in each species; their formation, therefore, cannot be attributed to accident; on the contrary, they seem to be organically necessary to the healthy exercise of the functions of these plants, giving them the requisite degree of buoyancy in the water.

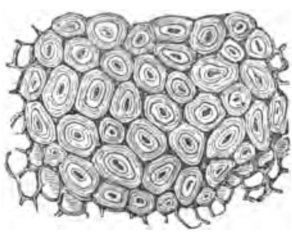
16. More frequently, however, the lacunæ are very irregular in their form, and are produced by the rapid growth of the parts resulting in the irregular destruction or distension of the cellular tissue. In these instances, their formation is in some sort accidental. The hollow stems of grasses and of the umbelliferæ are produced in this way.

17. After the first layer of protoplasm has been formed from the cambium and the cells constructed, as growth progresses, the cells, at first extensible and compressible, ultimately assume fixed and unyielding forms, owing to the internal deposition on their walls of sclerogen. The deposited matter includes all the various substances introduced into the circulatory system of the plant, and left by evapora-

tion in its cells; and every degree of its deposition may be seen from a slight increase of thickness of the cell-wall to the entire filling up of the cavity of the cell. The difference between sapwood and heartwood is caused, in fact, by a difference in the amount of the incrusting matter in the cells, and by an increase of which the former is converted into the latter. The indurated tissue which forms the cells of the stones of the peach, cherry, and other fruits is produced in this way.

18. Sometimes nearly the whole of the interior surface of the cells is thus thickened, the stratification of the matter being distinctly visible on the cross-section, as is well seen in the woody cells of the liber of the birch (Fig. 3), the cells

Fig. 3.

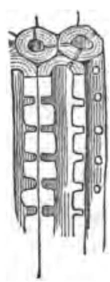


being nearly filled with a deposit of solid matter in concentric layers; occasionally, however, *certain parts* of the primitive layer of protoplasm *only* have the power of attracting from the fluid contents of the cells the incrusting matter, and of becoming thickened. This produces those dots and lines which are seen to mark the cell-walls of many species of plants, and which have been taken for pores or slits in the cell-wall; but the primitive membrane of the cell-wall is never perforated

or slit except accidentally; and these apparent pores and slits are, in reality, pits and chinks left by the non-deposition of sedimentary matter at that particular part of the cell-wall, and consequently visible by the greater amount of transparency there.

19. The chinks and pits in contiguous cells usually correspond, and hence one reason for this peculiar deposition of the sclerogen is very obvious. By it the lateral communications between the several cells composing the tissue are kept open, notwithstanding this thickening of their walls, the sap permeating through the vegetable tissues at these particular parts. These lateral passages and their nature are clearly shown in Fig. 4, which is a transverse and longitudinal

Fig. 4.



section of a portion of four cells of the woody tissue of Platanus occidentalis, or the Buttonwood, "highly magnified, showing the canals or deep pits in the thickened walls, and their apposition in adjoining cells; on the cross-section the layers of deposit are more plainly visible."*

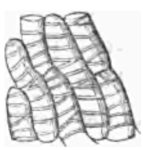
* Gray's Botanical Text-Book.

20. Although these pits and chinks are not real pores or openings in the cell-wall, yet they often become so with age, by the breaking away of the thin primitive membrane after the cell has lost its vitality.

21. By what power the sedimentary matter left on the sides of such tissue as this is prevented from choking up the pits and chinks is at present unknown. The sedimentary matter left by the evaporation of the fluid contents of the cells is certainly not deposited mechanically, as in the ordinary cases of evaporation; but it appears to be controlled in its disposition by the higher vital and physiological action in the cell-walls.

22. Sometimes, however, the secondary deposit itself is restricted to a delicate thread, which either occurs in rings or fragments of rings, or winds about the interior of the cell in a spiral (Fig. 5). The delicate membranous walls of such cells

Fig. 5.



are sometimes ruptured at maturity, by the elastic expansion of the spiral fibre within them. This takes place in the fructification of the hepatic mosses, which consists of spindle-shaped cells inclosing spiral threads called elaters, which, by their elastic expansion, burst the cell-walls and scatter the

spores. By a similar mechanism, the pollen is dispersed from the anther-cells of Cobæa scandens.

23. When the cell-walls of cellular tissue are composed of membrane without fibre, it is called *membranous* cellular tissue; but when the cell-walls consist of membrane and fibre combined, it is designated as *fibro*-cellular tissue. Some writers have recently distinguished other differences in the figure assumed by the cells, by the employment of a variety of technical terms expressive of those figures. But this is only multiplying unnecessarily the technicalities of the science. The general term, parenchyma, will suffice to distinguish a tissue composed of cells, from a fibrous tissue, or that which is composed of fibres or tubular vessels.

24. Cellular tissue enters largely into the composition of all plants, forming the pith of trees, the pulp of fruits, and filling up the interstices between the fibrous network of the leaves. There is an extensive tribe of plants which are wholly composed of this tissue, and as they produce no flowers, they have been for these reasons called by botanists *cellulares* or flowerless plants. The orders comprised in this division are the fungi, lichens, algæ, liverworts, and mosses. Of this tissue all plants in their earliest stage of development are entirely composed. Indeed, plants, however complex their organization, may all be traced by observation nearly or quite to a single cell; which cell, endowed with the power of self-propagation equally with the fully developed plant, gives rise to other cells, each being individually possessed of the same powers, and so forms the whole mass of the plant.

The woody and fibrous tissue which is so beautifully spread out horizontally in the framework of the leaves of plants, and which constitutes the substance of their more solid parts, is, therefore, only a peculiar transformation of cells which are, in fact, the basis and origin of all the other forms of tissue.

CHAPTER II.

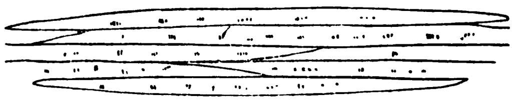
WOODY AND VASCULAR TISSUE.

25. It has been shown (4) that every plant consists of a series of cells aggregated together, having a certain arrangement, and developing into a certain regular form, according to fixed natural laws. The cells thus aggregated together constitute what botanists call a tissue, which tissue, according to the forms which the cells assume, is designated as cellular, vascular, and woody tissue. These are the three leading forms; but, in the study of nature, we must accustom ourselves to consider that there are transition forms, and never to believe that one and the same type remains unchanged. With this qualifying remark, we can now very properly investigate,

26. *Woody tissue*, or, as it is termed by some writers, fibrous tissue, or Pleurenchyma (πλευρά a rib, and χευμα anything effused or spread out), Fig. 6, consists of vesicles of cellular tissue drawn out into fusiform tubes of extreme tenuity and toughness, which lie close together and overlap each other at their tapering extremities, so that they are, as it were, spliced together. These tubes, united together in bundles, constitute the wood of the stem, and form those long coarse fibres which stretch through the plant lengthwise. Issuing from the side of the stem in distinct fasciculi or bundles, this woody fibre

forms the more solid parts of the petioles or stalks of the leaves; it is seen spread out horizontally in their framework, and in consequence of its constant tendency to anastomose, its subdivisions or branchlets, which are ramified out

Fig. 6.



amidst the green cellular parenchyma, even to the minutest visible fibre, and continued beyond the limits of unassisted vision, run into each other, forming that delicate and beautiful network which is visible to the eye in the leaf. It is owing to the vertical development of woody fibre that a piece of wood splits more readily in the direction of the stem (longitudinally) than when broken across (transversely).

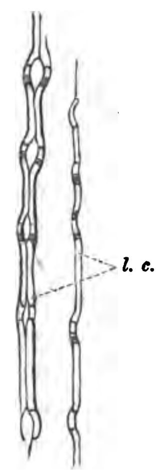
27. Woody fibre, in the earlier stages of its growth, contains fluid, which it carries from the roots, through the stem and branches, into the leaves and extremities of the plant. In the progress of growth, however, its walls become thickened by deposits of sclerogen; the caliber of the tubes diminishes, until, at length, as in the heartwood of trees, their tubular character is wholly obliterated.

28. The sclerogen thus deposited is generally spread out uniformly over the interior parietes of the tubes, so that bands, lines, and other markings are seldom seen in the walls of the cells of woody fibre. It is necessary, however, to except the fibre of pine woods, which exhibit large saucer-like depressions in the outer walls of the tube, with a dot in the centre, where

the sclerogen has not been deposited, and, consequently, visible by the greater transparency of the tubular walls in that part. The disks, or saucer-like depressions on the walls of two contiguous tubes, are applied to each other, whereby a small space is left between them, similar to the cavity left between the concave surfaces of two watch-glasses. In some fossil woods, pieces of silica, like double convex lenses, have been removed from these cavities, so as to leave no doubt as to the nature of these interspaces between the fibres, of which they were clearly the casts.

29. These circular markings in the fibres of pine woods are,

Fig. 7.



therefore, caused by cavities formed by the concave depressions or lenticular cavities, *l, c,* between the walls of two contiguous tubes, the centre of each depression being thin and transparent, and producing the dot seen in the centre of the

disk. These circular markings or disks are found in single, double, and triple rows. When there is more than one row, the individual disks are either opposite to each other, as in ordinary pine wood, or they alternate with each other, as in Araucarias. Mr. William Nichol, of England, and Prof. Bailey, of West Point, were the first to apply these characters to the determination of fossil woods, thus revealing the true nature of some of the earliest vegetation of the earth.*

30. Plants are durable and strong in exact proportion to the amount of woody fibre which enters into their composition. The lowly mosses and other orders of cellular plants scarcely rise more than a few inches above the ground; but when woody fibre begins to form amongst the cells, additional strength is given to the vegetable fabric, and plants are developed into herbs, shrubs, and assume the noblest arborescent forms.

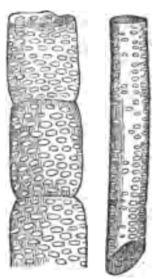
31. *Vascular tissue.*—This consists of a series of vesicles of cellular tissue, having fibre generated spirally in their inside, drawn out into membranous tubes tapering to either extremity, the walls of the tubes being absorbed at the points where they overlap each other, so as to allow of direct communication between them. More frequently, however, these tubes, instead of tapering, terminate abruptly at their extremities, and when this is the case, their origin from a series of elongated cells, placed end to end, is often beautifully apparent in the remains of the persistent parietes of the cells which are seen along the cavity of the tube, and by which its continuity is not unfrequently interrupted.

* Balfour's Class-Book of Botany.

32. As the vascular tissue in plants is only a modification of the cellular, we find in it all those characters which we have already described in the cells of the cellular tissue. Vascular tissue sometimes assumes the appearance of dotted or pitted ducts, which are continuous tubes of very conspicuous caliber or bore, which have been formed out of a series of porous cells, placed end to end, the walls of which have been absorbed in the progress of growth. The open mouths of these ducts are conspicuous to the naked eye on the cross section of the stems of the oak, poplar, and willow, rendering apparent the limits of each year's growth in the successive rings of the stem. The tubular tissue, formed by porous vessels, is termed Bothrenchyma (βόθρος, a pit). Fig. 8 is a portion of a dotted duct from the vine, evidently made up of a short series of cells. Fig. 9 is part of a smaller dotted duct, showing no appearance of such composition.

33. When cells containing spiral deposits of sclerogen are

Fig. 8. Fig. 9.



placed end to end, and their parietes absorbed, then vascular tissue takes the form of scalariform, annular, and spiral ducts,

which are simply open membranous tubes containing spiral fibre lying together in close coils in the tube, or with the coils more or less separated, or broken into rings or bars, *by the elongation of the tube after the formation of the spiral.* All these different forms of the spiral deposit may be seen in the common garden balsam, very frequently in the same duct. This form of vascular tissue is called Trachenchyma (*trachea,* the windpipe), on account of its resemblance in appearance and in functions to the trachea or air-tubes of animals.

The annexed illustrations are taken from the *Botanical Text-Book* of Dr. Gray:—

Figs. 10. 11. 12. 13. 14. 15. 16.

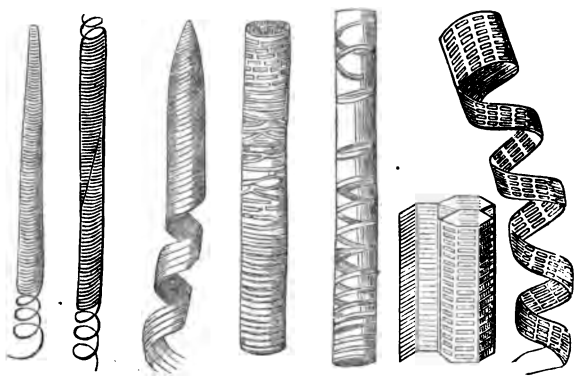


Fig. 10. A simple spiral vessel, torn across, with the thread uncoiling.
Fig. 11. Two such vessels joined at their pointed extremities.
Fig. 12. A compound spiral vessel, partially uncoiled, from the Banana.
Fig. 13. A portion of a duct from the leafstalk of Celery; the lower part *annular,* the middle *reticulated,* and the thread at the upper part broken up into short pieces.
Fig. 14. Duct from the Wild Balsam or Jewel-weed; the coils of the thread distant; a portion forming separate rings.
Fig. 15. Scalariform ducts of a Fern, rendered prismatic by mutual pressure.
Fig. 16. Similar duct of a Fern, torn into a spiral band.

34. Spiral fibre usually consists of a single filament, but sometimes numerous fibres are united together, assuming the aspect of a broad ribbon or band, as may be seen in the stems of the banana or the asparagus. When the spiral coil remains unbroken, it is so strong and tough, in comparison with the delicate cell-wall on which it is deposited, that it may be torn out and uncoiled when the vessel is pulled asunder, the membrane being destroyed in the operation. This capability of being unrolled characterizes the true spiral fibre.

35. Spiral fibre is soon known, and familiarized to the mind, by breaking asunder almost any young shoot or leaf-stalk (as for instance that of the geranium or strawberry), and gently separating the broken ends, when a number of white glistening fibres of extreme delicacy, and not unlike the threads of the spider's web, will be seen running from one portion to the other. If these threads be placed under the microscope, it will be evident that they had lain in spiral coils, which are partially straightened through being drawn out, just as when a spiral spring is strained. These vessels were first discovered by Henshaw, in the year 1661.

36. Vascular tissue is never wholly filled up by deposits of sclerogen, the spiral fibre within it keeping the canal of the tubes constantly open. The accurate experiments of Bischoff have led to the conclusion that the perfect spiral duct or spiral vessels are filled with air which contains a large amount of oxygen in its composition. This oxygen, the result of the chemical compositions and decompositions going on in the interior of the plant, spiral vessels convey from the central part of the plant to its young shoots and leaves, the

network of which consists of woody fibres inclosing spiral vessels as a protecting sheath, and through the pores of the leaves and young shoots this oxygen escapes into the atmosphere. The other kinds of vascular tissue, particularly the porous, convey fluid which they distribute horizontally and longitudinally through the vegetable system. Spiral fibres are abundant in young plants and shoots; in the hard stems of trees and shrubs, they chiefly surround the pith.

37. The cell has now been shown to be the type of all the tissues of plants, and to be the basis of the vegetable structure. To the elongation of cells and to the deposition of thickening layers in their interior, the various kinds of vessels owe their origin. In the lower tribes of plants, such as mosses and algæ, the cells multiply in their primitive form, which they retain during the life of the plant; in vegetation of a higher grade, some of the cells early undergo the transformations already described, and become elongated into tubes of vascular and woody tissue, which tubes, imbedded in the parenchyma or cellular tissue, impart additional strength and solidity to the vegetable structure, conveying fluids and air to every part of it. The beautiful researches of Treviranus and M. Mirbel have proved that these vessels are only a series of superposed vesicles of membranous and fibro-membranous cellular tissue, the septa of which have been absorbed in the process of growth. These facts may be verified by direct observation on the young and growing tissues of plants, if those tissues be placed beneath the microscope. All the different forms of tissue which we have described, pass insensibly one into the other through intermediate gradations, and

in this manner the origin of the whole of them from the simple cell may be distinctly traced. Such are the beauty and simplicity of those laws which govern the development of plants! Such are the simple means with which nature accomplishes the sublime results of vegetation!

CHAPTER III.

ON THE DEVELOPMENT AND FUNCTIONS OF CELLS.

38. As all the parts of plants are fabricated out of cells, it follows that growth, or the extension of their parts, is the result of the development of new cells, and that the size and form which plants assume must be owing to the number and nature of the arrangement of the cells thus developed. All the varieties in the size, form, and duration of plants are, therefore, simply the result of different degrees of cell-evolution, and the same plan and principle of structure pervade the whole of them. To show that this is really the case is the object of the present chapter.

39. In all plants which consist of more than one cell, or of a series of cells united together, a distinction must be made between Vegetative cells, or those which aid in nutrition and growth, and Reproductive cells, or those which continue the species. All such plants continue to grow or extend in a given direction so long as their vegetative cells continue to develop; but when the reproductive cells make their appearance, the growth or extension of their parts in that direction ceases. Now the endless variety of form and size amongst plants is owing to peculiar modifications in their common organs of vegetation and reproduction. Each species of plant appears to be governed by peculiar organic laws, which

are probably only a modification of one universal principle of vital action.

40. In Forest-trees, the process of growth, or cell-evolution, continues for centuries; in shrubs, for a much shorter space of time: hence, the vast size to which the former attain, and the dwarfed growth of the latter. In these plants, the cells, as they increase in number, become specialized, or arrange themselves into definite parts, such as root, stem, and leaves, each having distinct functions to perform in the vegetable economy, whilst their reproductive cells are contained in certain metamorphosed and terminal leaves termed *anthers*, and are the final results of the physiological action of an exquisite floral apparatus bright with the most resplendent hues and colors. Forest-trees and shrubs are the highest forms of vegetable development on the face of the earth. Not only do they surpass the herbaceous plants, that grow beneath their shade, in size and in the duration of their life, but they are to a considerable extent more *composite* in their mode of growth. The forest-tree is not a simple individual, as is usually supposed, but a community of individuals. Properly speaking, the simple plant consists only of a stem, root, and the first pair of leaves. The succeeding evolution of leaves is only a continuation of the first process of growth, whilst each bud is an actual repetition of the plant, the only difference being that the bud or new plant has no free radical extremity, like the parent plant, developed on the soil, its root being intimately blended with and contributing to the formation of the wood of the stem on which it grows.

41. In Shrubs and herbaceous annuals and perennials, there

is a similar development of buds or new plants on the stem, but not to the same extent; hence they do not attain the same elevation above the ground. In the lower forms of herbaceous vegetation, the buds or stem-plants become successively less and less evolved, until at length they disappear altogether from the stem, which itself is so contracted in its growth as to be hidden in the earth. This is the case with the hyacinth, lily, and other bulbous-rooted plants. The bulbs of these plants are considered by botanists to be subterranean buds or undeveloped stems, to which they are in every respect similar. The outer leaves of these buds retain their rudimentary scalelike appearance, and form a protective covering to the inner leaves, which grow in a tuft on the ground, the flower-stem rising from their centre.

42. In all these instances, the parts consist of millions of vegetative and reproductive cells, especially when the plants attain any considerable degree of elevation above the earth's surface, as in the case of forest-trees, where the evolution of cells goes on for centuries. In the lower forms of vegetation, the vegetative and reproductive cells become successively less and less evolved, until at length, by successive degrees of simplification of structure, all distinction into organic parts gradually and finally vanishes.

43. In the beautiful and interesting tribe of plants called Ferns, we have a still greater simplification of vegetable structure. Stem and leaf are now blended into what is designated a *frond*, which appears to partake of the nature and office of both, whilst in place of the beautiful flower there is only a

collection of mere dustlike spots or lines of reproductive matter, situated on the margin or under surface of the frond.

44. But the structure of Ferns is complexity itself when contrasted with the beautiful simplicity of the tribes of plants beneath them. When we come to examine the Mosses—those miniature representations of the arborescent forms of nobler plants—we are struck with the extreme delicacy, simplicity, and exquisite beauty of their structure. There is a certain degree of solidity about the organization of forest-trees, flowering-plants, and ferns, the result of different amounts of ligneous matter or woody fibre entering into their composition. These substances impart strength and stability to the vegetable fabrics, and plants so organized will grow to a considerable height. But mosses are wholly cellular in their organization, and, for this reason, never rise more than a few inches above the ground. They usually possess a sort of stem, around which their minute leaves are arranged with the greatest regularity. These minute leaves, when examined carefully with a microscope, are seen to have an entire and sometimes serrated margin, and to contain condensed cells in the form of ribs or nerves. Their fructification is contained in little capsules, or urn-shaped bodies, which are borne on the summit of their filiform fruit-stalks or setæ. These capsules contain the minute spores or reproductive matter. The beautiful mechanism by which its dispersion is effected will be described another time. Few common objects appear more interesting than the little mosses growing on the bark of trees or barren rocks, amidst the gloom and desolation of winter, which require neither skill nor the assistance of instruments for the detection of

their beauties. The same distinction of parts into root, stem, and leaves is therefore still seen in these minute, but exquisitely beautiful plants, although the root no longer springs from one extremity of the axis of growth, but from every part of it.

45. In the Liverworts, the leaves are reduced to mere imbricated scales, and in the lower forms become blended into a continuous expansion of vegetable matter called a frond.

46. In the Lichens, vegetation is reduced to its last degree of simplicity. Root, stem, and leaves have now disappeared, and the whole plant is blended into a flat expansion or bed of vegetable matter, called a *thallus*. The thalli of the higher forms of lichens are foliaceous, consisting of several layers of cells radiating out on all sides; some of these cells are reproductive, and exhibit the spores in the shape of powdery heaps called *soredia*, or else they become organized into saucer-like bodies called *shields*, in which the spores are imbedded. In the lower forms, the thalli of these plants are crustaceous or even pulverulent, the whole plant assuming the appearance of mere powder. In this case the cells no longer remain together, but are free and unformed, any cell being capable of originating a new individual. The plant and cell are now identical.

47. Nature passes through the same transitions in the Seaweed tribe. Certain Algæ or sea-weed are of a frondose, others of a filamentous structure, whilst some appear as mere scum on the surface of the waves. In these instances, the plants consist of cells developing in length and breadth, of cells developing in length only, or of a single cell. The same remark applies to the Fungi, where nature only finishes with

plants of a single cell. Here then we have vegetation reduced to its simplest terms. The basis of the superstructure of the whole vegetable world is a single cell.

48. We have seen that the fabric of plants is wholly made up of cells, and that growth is simply the result of the evolution of new cells. The process of cell-growth, which is really the key to much that remains mysterious in the fabrication of plants, may be most successfully studied in these simple plants. A review of the life of the cell, and of very simple plants consisting of a few cells, must necessarily precede any successful attempt at the comprehension of higher and more complex vegetation. This has been felt to be the truth, and hence this subject has recently taxed the powers of the ablest minds. Much remains involved in obscurity; but scientific and microscopical investigation of these humble plants has already revealed many deeply interesting discoveries in reference to cell-growth, tending to throw light on the wonders and beauties of the vegetable creation.

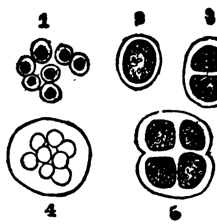
49. Now as the plan of structure in the more highly organized and complex plants can only be understood by studying the operations of nature in detail, as exemplified in the simpler vegetable forms, we shall commence with these first, this being plainly the most natural and philosophical method of investigation. Let us begin, then, with

50. *Plants composed of a single cell.*—Some of the lower forms of the Algæ and Fungi furnish us with examples of plants thus organically simple, and they are especially interesting, as furnishing us with the simplest indications of those processes of cell-growth and reproduction, on an accurate

knowledge of which rest the very foundations of scientific botany.

51. The Plant-cell, as it is termed by Dr. Schleiden, constitutes an entire vegetable, without organs, imbibing its food by endosmosis through every part of its surface, which it converts into the materials of its own enlargement and growth, and finally into new cells which constitute its progeny. Being without lateral compression of any kind, the plant-cell necessarily takes a globular form. We select, as an illustration of the plant-cell, the Protococcus nivalis, or red snow-plant, found in the arctic regions, and which also occurs on damp ground in much lower latitudes. In Fig. 17, 1, we have

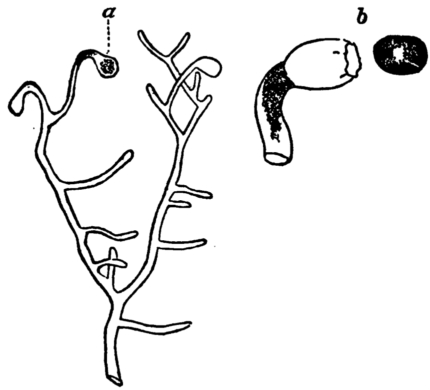
Fig. 17.



several individuals of this plant slightly magnified to show the nature of the reproductive process. New cells are seen to originate in the interior of each plant-cell, which gradually take their place, and the new generation thus produced enlarges and gives rise to a new progeny in their interior as before. In this manner, this simple vegetation grows on from age to age: 4 represents a more highly magnified individual of the Protococcus nivalis, showing more distinctly the new cells

forming in its interior. The green pulverulent matter which appears on old walls, and on the bark of trees, consists of an unformed mass of free globular cells, which grow and reproduce in this simple manner. Here we have the starting-point of vegetation, the beginning of the formation of those vegetable elements which, in their future development, shall clothe the earth's surface with the richest forms of life and beauty. In other species of plant-cells, the mode of reproduction is somewhat different. In Chroococcus rufescens, 2, the plant-cell takes an oval form; a partition then appears across its cavity, as represented at 3, dividing it into two cells. These two cells are again subdivided by the formation of another septum at right angles to the first partition, as is seen at 5. The four cells thus formed enlarge and ultimately separate, constituting four new individuals, which propagate in like manner. In Oscillaria, the plant-cell becomes elongated, or it may become elongated and branched, as is the case with the species Vaucheria, which forms one kind of those delicate and flossy green threads abounding in fresh water, and which are popularly known in some places as brook-silk. Fig. 18 is a magnified view of Vaucheria clavata, which consists of a single cell of unbroken caliber, furnished with branches. In one of these branches, at *a*, a spore is forming. *b* represents the end of the branch more magnified, with the spore escaped from its burst apex. In this instance, the ramifications of the cell foreshadow, as it were, the elongation and ramification of cells in the stem and branches of more highly organized plants.

Fig. 18.

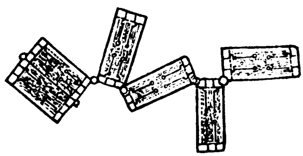


52. *Plants composed of a single row of cells.*—In this instance, the cell is multiplied by division combined with subsequent expansion which takes place in one direction only. A cell is first elongated, and a partition is seen to project across its middle, by which it is divided into two cells; one of these cells again elongates, and is again subdivided in a similar manner; in this way, a plant is produced consisting of a simple or branching series of cells placed end to end. Such plants can be seen in any shallow stream of water which is exposed to the light. They appear like threads of vegetable matter, and collectively form that bright-green ooze which attaches itself to the stones and pebbles of the stream. The extension of the parts of plants, or their growth, in all ordinary cases is effected by this mode of cell-multiplication.

53. In the simplest plant in nature, the plant-cell, both the reproductive and nutritive processes are carried on by the same

cell. So also in the Diatomaceæ, a species of marine algæ, where the *union of plant-cells is only temporary*, the organs of nutrition and reproduction are still identical. The cells of these plants are at first united, but afterwards spontaneously disarticulate and break up, exhibiting well-marked spontaneous movements, insomuch that some naturalists have referred them to the animal kingdom, to which they certainly approximate. Fig. 19 shows this process of disarticulation in Dia-

Fig. 19.



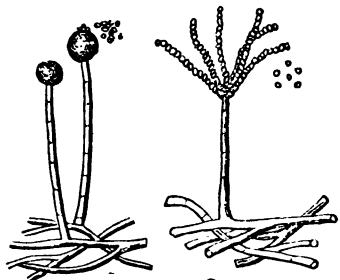
toma marinum after the consummation of the reproductive process. The cells thus separated, under suitable conditions, individually develop into new and independent plants.

54. But when *plant-cells unite together permanently*, as they do in the higher forms, the organs of nutrition and reproduction are no longer identical or confined to the same cell; on the contrary, some of the cells are specialized or set apart for nutrition, and others for reproduction.

This is beautifully exemplified in the Mucor, or bread-mould (Fig. 20), which consists, as to the creeping part at its base, of long, threadlike and branching cells, the partitions of which have been wholly absorbed, so that they form continuous tubes, whilst its upright portion, or stem, is composed of a single row of cells, formed by the process of division

already explained, the terminal cell containing the reproductive matter or spores. In Fig. 21, the Penicillum glaucum,

Fig. 20. Fig. 21.

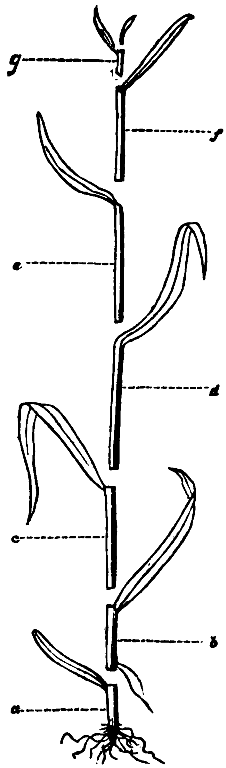


another mould, we have a somewhat different arrangement of the reproductive cells, which, instead of being inclosed in a solitary terminal cell, are arranged side by side, forming a number of beadlike branches at the summit of the stem. These cells ultimately separate, and grow into new individuals.

55. When plant-cells unite together permanently, as in the bread-mould, their union with each other evidently corresponds to the union of phytons on the stem of flowering-plants, and forest-trees. It has been shown (p. 40) that a tree "is not a simple individual, as is usually supposed, but a community of individuals." Every bud which develops into a branch is in fact a phyton (φυτον, a plant), or new plant, and is actually capable of becoming such when taken off from the stem and introduced into the soil as a cutting. A tree is the result of the evolution of a countless number of these super-

posed phytons or buds which are developed successively on its stem or axis of growth, and differ only from "the parent plant developed on the soil," in having "no free radical extremity;"

Fig. 22.



their roots commingling with and "contributing to the formation of the wood of the stem on which they grow." Fig. 22 is

a diagram illustrating the development of a monocotyledonous plant by superposed phytons; *a—g*, the successive phytons. Sometimes the lower phytons develop adventitious roots from the side of the stem, as represented at *b*, which roots are intended to act as props or mechanical supports. This is well seen in the lower joints of the stem of the Zea Mays, Indian corn. Now these buds or phytons, although capable of growing independently, remain through life united to the parent stem on which they develop and form by their united growth the individual tree. In like manner, when plant-cells unite together in a linear series to form the individual plant called the bread-mould, each plant-cell in the series is capable of propagating the species when separated from the others (which it actually does, as we have already seen, when this separation takes place naturally), and each plant-cell is also only a repetition of the same process of growth which took place in the development of the primary plant-cell. The bread-mould is therefore a composite plant formed by the union of plant-cells, each of which is capable of forming the germ of an independent existence, and of propagating the species, although it remains through life in union with the parent plant-cell forming the individual bread-mould, just as the permanent union and development of a superposed series of phytons form the individual tree.

56. It is therefore clear that the little bread-mould which nature constructs from decaying organic matter in a few short hours, consisting of a few united vegetative cells and a single terminal reproductive cell, is only a simpler expression of the same law which operates in the production of the forest-tree.

The extent of cell-development in forest-trees and flowering-plants is alone different; the phenomena themselves are precisely analogous. In forest-trees and flowering-plants, the vegetative cells, as they develop in countless millions, assume distinct organic parts, as root, stem, and leaves, whilst the reproductive cells are seen in the form of beautiful and highly organized flowers. In the bread-mould, all such distinctions vanish, and the organization of the parts is reduced to the utmost degree of simplicity.

57. Let us pause for a few moments, and reflect on the simplicity and beauty of these admirable productions of nature. Think of the Liriodendron tulipifera, or tulip-tree, the pride of the American forests. Its wide-spread and powerful roots, its tall and massive stem, its glorious and far-extended canopy of foliage and flowers—this is the result of centuries of assimilation from inorganic matter, of the evolution of countless myriads of cells. Now look at the little bread-mould, which nature constructs from decaying organic matter. A few interwoven tubular filaments form the root, a single row of vertical cells the stem, whilst a solitary terminal cell is the humble representative of the flower. Here, then, we have the whole of the vegetative and reproductive process, seen as it were in miniature beneath the microscope, and brought within the compass of a few short hours.

58. Yet, though nature has thus simplified her operations, how little do we in reality know about them! We do not know how the cells of the bread-mould originate, why they develop in this particular form, and why, after a certain number of vegetative cells have been developed, a solitary termi-

nal reproductive cell should make its appearance. Could we but answer these simple questions, we could explain the formation of vegetable out of mineral matter, the laws which govern the evolution and special arrangement of cells into the specific forms assumed by plants, and the mechanism of the entire vegetable creation. But, although the subject of cell-development has recently taxed the powers of the ablest minds, it is still confessedly obscure. A more thorough investigation of the simpler forms of vegetation seems to be necessary to the understanding of this important subject.

59. It would seem, from the facts already brought to light, that there are two methods of cell-multiplication by which growth and reproduction are effected, which are but modifications of one and the same process of division: 1. The cell is multiplied by the formation of a partition across its cavity by which it is divided into two cells; one of these cells elongates, and is again subdivided in a similar manner, the original wall of the cell remaining. In this way, a single cell gives rise to a row of connected cells, when the division takes place in one direction, and to a plane or solid mass of cells, when it takes place in two or more directions. This is the ordinary mode of increase in all growing or vegetating parts. 2. The cell is propagated by division of its interior cavity into two, four, or a greater number of free new cells, the original cell-wall being absorbed or perishing in the operation. By this method the reproductive cells of pollen formed in the anthers of all flowering plants, and the spores or reproductive cells of flowerless-plants, originate.

PART II.

ON THE

COMPOUND ORGANS OF PLANTS.

THE CRYPTOGAMIA, OR FLOWERLESS PLANTS.

PART II.

ON THE COMPOUND ORGANS OF PLANTS.—THE CRYPTOGAMIA, OR FLOWERLESS PLANTS.

CHAPTER I.

CELLULARES, OR CELLULAR PLANTS.

60. The cells have now been separately considered, and the student has been made acquainted with such facts respecting their origin and anatomical peculiarities as are afforded by the present state of science. We are now about to investigate the phenomena of the cells in a state of combination, or when united together into those masses of tissue which constitute definite organs.

61. In the lower forms of vegetation, such as algæ or sea-weed, lichens, and mosses, the cells retain, to a great extent, their primitive form, being but slightly altered by the compression and growth of the parts. For this reason, these plants have been called by botanists cellulares or cellular plants.

62. These cellular plants commence the vegetable series, and are by far the most interesting in the vegetable kingdom.

In them we see organization brought, by successive degrees of simplification, to the utmost degree of structural simplicity. We have seen that all the different forms of tissue found in plants are only modifications of the cellular, all originating in the simple cell as a point of departure; and in like manner, when we look on the plants themselves individually, and follow the operations of nature in detail, as seen in the lower vegetation, it may be truly said that the same simple cell is the starting-point of the plants themselves, considered as individuals.

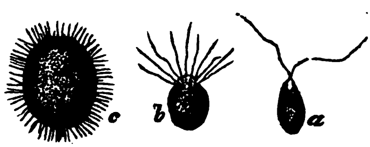
63. It is not necessary for cell-development to be carried to any great extent in order to constitute the fabric of a true and perfect plant. All the organs which constitute the most complete vegetable concur in the exercise of one or the other of two general functions, nutrition and reproduction, and we have seen that these functions may be exercised by plants composed of a single row of cells strung end to end, or may be confined to one and the same cell, as in the Protococcus and the various species of leprarias or pulverulent lichens (51), which are plants composed of a mass of free spherical utricles, or cells filled with granulations of various colors.

64. It is at this point that the Vegetable makes the nearest approach to the Animal kingdom, which also has for its starting-point a single spherical utricle or cell, which differs only from the vegetable cell in that it possesses the property of motion. The two series, the animal and vegetable, therefore, commence in the same manner, and hence it is not in plants which are the most perfect, but, on the contrary, in

those which are the most simple, that we meet with the nearest analogies to the animal kingdom.

65. It is in the algæ that the vegetable makes the nearest approach to the animal kingdom. It is amongst these plants that we observe the curious phenomena of zoospores (ζωὸς living, and σπορά, a spore), movable spores, which enjoy truly an animal life at the moment when they are emitted from the tube which contains them, and afterwards germinate and develop into a vegetable, fixed and immovable. In Vaucheria (51), Fig. 18, the production of spores takes place in a cell situated at the extremities of the filaments, which becomes swollen so as to acquire a clavate form, is densely filled with granular matter, and finally bursts at the apex and discharges the spore *b*. The spores thus emitted are furnished with vibratile appendages resembling ciliæ (*cilium*, an eyelash), which enable them to swim about in the water; and in this state they have been actually figured by Ehrenberg as animalculæ!! In the course of a few hours, however, after their emission, the ciliæ are absorbed, the spontaneous movements cease, they become attached to some immovable substance in

Fig. 23.

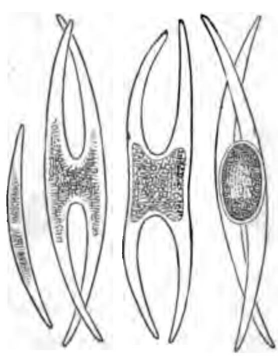


the current, and begin to germinate, elongating and undergoing division by septa in the usual manner. In Fig. 23, we

have represented, *a*, spore of Conferva glomerata; *b*, Prolifera rivularis; *c*, Vaucheria ungerii, after Thuret.

66. In plants composed of a cell or a single row of cells, even at this stage of vegetation, a process of great physiological importance is observed, the evident equivalent of bi-sexuality in the higher orders. In Zygnema and other Confervas, which consist of plants composed of rows of cells, the cells, at a certain period, bud out laterally, and coming in contact with similar buds on contiguous filaments, the septa become absorbed, a free communication is opened between the cells of the two filaments, the contents of one cell then pass into the other, and the result is the production of the germinating spore. The common fresh-water plant, called the Hydrodicton utriculatum or water-net, is composed of filaments which have united in this manner, and in this case with so much geometrical regularity as to give the plant the appearance of a green net, inclosing hexagonal and pentagonal spaces. The process is termed conjugation. In Fig. 24, *a*, we have a

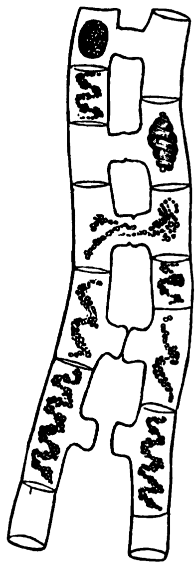
Fig. 24.



a *b* *c* *d*

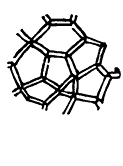
magnified view of an elongated plant-cell, the Closterium acutum, after Ralfs. *b* shows two of these plants in a state of conjugation, and the granular contents of one cell passing into

Fig. 25.



the other; *c*, the contents of the two cells in a more highly condensed state; *d*, the fully formed spore. In Fig. 25, we

Fig. 26.



have two filamentous plants of Zygnema, showing the different stages in the process of conjugation, which are seen from below upwards. Fig. 26 is a portion of the network of Hydrodicton utriculatum.

THE LICHENS.

67. *Plants composed of a tissue of cells combined in one plane.*—In this case, the cell is multiplied, as before, by division, which takes place in two or more directions, giving rise to a plane or solid mass of cells, some of which are specialized for nutrition, and some for reproduction, as already explained. Only the simplest forms of these plants consist of a single layer of cells. Most frondose sea-weeds, as well as lichens and liverworts, are made up of several such layers.

68. The term *frond*, or, as it is called in the lichens, *thallus*, is applied to those simple expansions of vegetable matter which are neither leaf nor stem, but combine the appearance and the office of both.

69. The thalli of lichens are composed wholly of cellular tissue, and are either pulverulent, crustaceous, foliaceous, or arborescent; these different forms depending, of course, on the different ways in which the cells are developed and combined together. Those portions of the thallus which contain the sporules are called apothecia (from αποθήκη, a repository). In the lowest forms of lichens, the pulverulent thallus overspreads the surface of rocks and the bark of trees, in the form of an inert leprous crust, resembling on the rocks stains of color. Sometimes the fructification is included within the crust and depressed below its surface. The cortical layer or

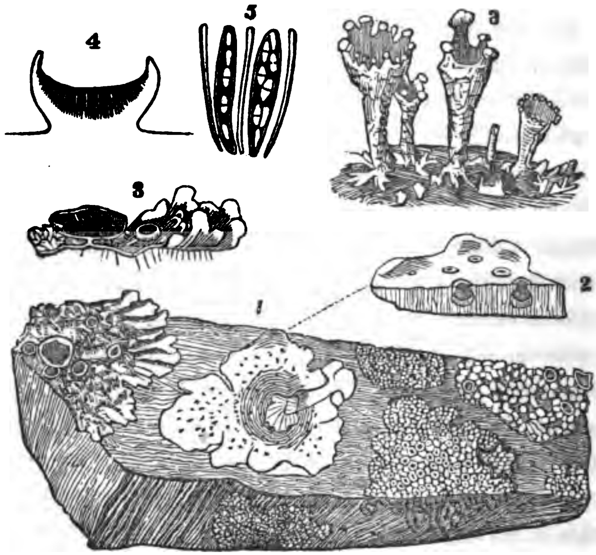
outer bark of the lichen nearly covers the apothecia thus immersed, and air and light are admitted only through a small aperture called an ostiole (*os*, *oris*, a mouth). In other species of pulverulent lichens, the fructification reaches the surface, and is seen in the form of a dark convex nucleus of cells. In the crustaceous and foliaceous lichens, the fructification rests on the surface, or is situated on the margin of the thallus in saucer-like bodies or shields, the cortical matter of the thallus forming a border round the nucleus.

70. In the higher developments of lichens, the thallus rises into a kind of axis, the cortical matter forming a podetium or stalklike process containing the apothecia at its summit; or it assumes an arborescent appearance, as in Cladonia rangeferina, the reindeer-moss, or in Usnea, the beard-moss, which at first grows upright, but afterwards becomes pendulous with age, and forms those long gray tufts of vegetable matter which hang from the boughs of trees. In these instances, the fructification is contained in little circular shields at the extremities of the branches.

71. The annexed illustrations, from the *Botanical Text-Book* of Dr. A. Gray, convey a very good idea of the organization of the different species of lichens. Fig. 27, 1, is a stone covered with several species of pulverulent, crustaceous, and foliaceous lichens. In the centre of this stone, we have Sticta miniata, a lichen whose apothecia are immersed in the substance of the thallus; 2 is a piece of its thallus magnified, in which the ostioles and immersed apothecia are seen more distinctly. On the right-hand margin of the stone, we have crustaceous lichens, the fructification being visible on

their surface in the form of dark nuclei or spots; and on the left-hand margin we have a foliaceous lichen, Parmelia con-

Fig. 27.



spersa, with its fructification in shields or cups, the cortical matter of the thallus forming a rim or border round the nucleus; 3 is a piece of the thallus of Parmelia conspersa with a section through the apothecium; 4 is a magnified section of an apothecium, showing the young asci or sacs which contain the spores imbedded in the substance of the apothecium; 5 is a representation of two of these asci or sacs, with their contained spores and accompanying filaments highly magnified; 6 shows the podetium or stalk-

like thallus of Cladonia coccinea, a beautiful lichen found on the decaying stumps of old trees, and which bears its fructification in rounded red masses at the summit of its podetium.

72. It not unfrequently happens that the reproductive matter of lichens appears on the surface or margin of the thallus in the form of irregularly-shaped powdered masses of spores, soredia (*sorus*, a heap), which propagate either on the original thallus, forming foliaceous or squamulous expansions, or external to the original thallus, forming new individuals of the species.

73. The thallus of lichens, when it exists under the form of a membrane, is composed of three superposed beds or layers of cellular tissue; the cortical layer, which is formed of spherical utricles, containing interiorly granules of various colors. These cells have received the name of Gonidia, and constitute the soredia or masses of spores, which, when detached from the plant, form new individuals of the species. The medullary layer is situated immediately beneath the cortical, and is composed of both rounded and filamentous cells. The hypothallus or under surface of the lichens is composed of cellules elongated and cylindrical, the analogues of roots by means of which the plant attaches itself firmly to the substance on which it grows.

74. The limits of the three great families of cellular plants, the lichens, the fungi, and the algæ, have not yet been distinguished; and some naturalists, who have studied these tribes with great attention, are of opinion that a spore from any one of them will develop into a fungus, alga, or lichen, according to the medium in which it happens to be

placed at the time that its vegetative powers are called into action.

75. Algæ have been considered by some to be lichens growing in water, and in the *Synopsis of the Lichenes*, recently published by Edward Tuckerman, A. M., of Boston, lichens are defined to be "perennial, aerial algæ." It is true that the hard, dry, scaly, and almost indestructible thallus of such species of lichens as grow on the surface of exposed rocks, old fences, or the bark of trees, is very unlike the soft, easily decomposed, and leaflike frond of the algæ or sea-weed; nevertheless, when lichens grow in moist situations, they approximate towards the algæ in point of organization, and in some cases, as in the genus Collema, it is difficult to fix the group to which they belong. Certain it is that this tribe of plants deserves the closest investigation of the physiologist. In them we have the simplest expression of the laws of vegetable life, and they are probably the best starting-point in the study of the vegetable creation.

76. Hitherto, the plants investigated have been stemless, leafless, and rootless, presenting to the eye the appearance of powdery, filamentous, or flat foliaceous expansions of vegetable matter, having the reproductive cells imbedded on the surface or restricted to the extremities. These plants, which are without any distinct root, stem, or foliage, have been called collectively Thallophtes, because they consist of a thallus or bed of vegetable matter; and the name is very appropriate, for the greater part of these rootless, stemless, and leafless vegetable bodies consist of a collection of cells commonly aggregated so as to make up a stratum or bed of vegetation

more or less compact, and which is without any definite figure. We are now about to enter on the examination of a higher type of vegetation.

HEPATICÆ, OR LIVERWORTS.

77. *Plants composed of a distinct axis and foliage, and which develop into root, stem, and leaves.*—This distinction of parts is first visible in the higher forms of the Hepaticæ or liverworts. The thallus, or vegetative part of the lower forms of these plants, is a lobed and continuous mass of green vegetable matter lying on the ground, and emitting root hairs from every part of its under surface; but in the higher forms of the Hepaticæ the vegetative part is distinctly foliaceous, although the organization of their minute leaves is of the simplest character, which resemble in some species a two-ranked series of imbricated scales, with an imperfect or rudimentary row of leaves (amphigastria) on the under side. In both kinds of Hepaticæ, the reproductive matter is no longer imbedded in the thallus or vegetative part; on the contrary, it is contained in special and distinct organs. A capillary peduncle, the type of a true stem, rises above the surface of the frondose, scalelike vegetation, bearing on its summit a valvular brown case or capsule, which contains the reproductive matter or sporules. This capsule is without an operculum or lid, and in most of the genera without a columella, dehiscing at its apex, and opening by four spreading valves.

78. Fig. 28 is an illustration of the workmanship which nature exhibits in the formation of Jungermánnia complanata, a species which is common on the bark of trees in moist

Fig. 28.

a. Jungermannia complanata in fruit, natural size. *b.* The fruit magnified, showing the perichætium or sheath, at the base, the peduncle rising from it, and the capsule at its summit not yet burst. *c.* The capsule split at its apex, and discharging its spores. *d.* The capsule empty, showing its four valves.

situations, and which may be found in fruit from January to April.

79. The spores of these plants are often mixed with spiral filaments called elaters. Spores are now generally regarded as produced by the agency of certain bodies analogous to the stamens and pistils of flowering-plants, called antheridia and pistillidia. These organs have been demonstrated more or less in all the orders of the Cryptogamia or flowerless plants.

80. In the hepaticæ, or liverworts, the antheridia appear on the fully developed plant. In the frondose species they are imbedded in the substance of the frond or thallus, and in the foliaceous species they are situated in the axils of the leaves.

MUSCI, OR MOSSES.

81. It is, however, in the mosses that the higher type of vegetation is fully realized. In them we have plants possessing a distinct axis and foliage; that is to say, a stem which rises from the soil growing onward from its apex, and which is symmetrically clothed with distinct leaves as it advances.

82. Few common objects are more interesting than mosses, which require neither skill nor the assistance of instruments for the detection of their beauties. The term *moss* is applied not only to the true mosses, but also to many lichens. The true mosses may, however, be always distinguished by their green color, whilst the lichens are generally grayish in their aspect, or of some other hue than green.

83. In the algæ and lichens there are no fixed forms assumed by these plants; they are also, generally, without any local habitat. Some of the lichens vegetate indifferently anywhere, on rocks, or the bark of trees, or on the ground, and vegetate in all climates, and at all seasons of the year. These plants certainly exhibit a low degree of life as well as simplicity of organization. They are amongst the slowest in growth of all plants, and the least subject to alteration from decay. Whilst alive, they scarcely exhibit any change through a long series of years; and, when dead, their forms and colors are scarcely altered by being dried.

84. But we are ascending the scale; and now commences the unfolding of a more elaborate organization, in which the conditions of development are necessarily more restricted, and a higher degree of life is manifested. The plants now about to be described grow only in certain soils, at certain seasons of the year, and are peculiar to certain climates, whilst they retain the same specific form from age to age.

85. Mosses generally affect a cool, moist, shady situation, and appear to be for the most part developed under the influence of humidity, accompanied with a low degree of temperature. Hence they prefer the shade of woods and rocks

facing the north, and are most abundant in the temperate regions of the earth. In tropical climates, they are found chiefly on the summit of mountains, where the heat and dryness of the climate are moderated by the elevation of the land. In summer, they are seldom seen, except in moist, shady spots, such as grow in tufts on the tops of walls, or the surface of exposed rocks, being burnt up, or as it were dried to dust, so that they escape our notice. Yet even at this season, a shower of rain will revive them and cause them to burst forth into verdure. But their beauty is evanescent; and they soon wither and disappear from the wall or rock on which they were seen. In autumn, as the temperature declines, the mosses make their appearance, and in winter they are found in perfection, beautifying this desolate season of the year.

86. The mosses are plants having a distinct stem or axis of growth, around which their minute leaves are arranged with the greatest regularity and beauty. These leaves, and, in fact, the whole plant, assume a regular specific form, being, as to their margin, entire, serrate, or denticulate, with condensed cells in their centre, which form a sort of midrib or nerve. Occasionally, however, the leaves are nerveless, as in Hypnum purum, a British species.

87. Sometimes the stem is procumbent, or creeps along the ground; the branches fork and spread, emitting rootlets from every part of their under surface, which doubtless perform their part in absorption; and the capsules or fruit come out laterally, or from the side of the branches. In other species, the stem takes an ascending direction, the rootlets are con-

fined to the lower extremities of the axis of growth, and the fructification is terminal, or comes out at the summit of the branches. Such mosses are evidently the higher representatives of the family. This is well seen in the genus Climacium dendroides, which has an arborescent growth, and presents the appearance of a beautiful tree in miniature.

88. Such mosses as have lateral fruit are called Pleurocarpi (πλευρά side, and καρπὸς fruit); those in which the fruit is terminal are called Acrocarpi (ακρα summit, and καρπὸς fruit).

89. If we carefully examine a moss in fructification, we shall soon see a number of urn-shaped bodies, sporangia (σπορὰ a spore, and ἄγγος a vessel), supported on capillary peduncles, which rise from amidst the foliage. Surrounding the base of the peduncle, a number of leaves will be perceived somewhat different in exterior configuration from the rest, which serve as a kind of calyx, inclosing the fructification in the earlier stages of its growth, and which are called the perichætial leaves (περὶ around, and χαίτη a bristle).

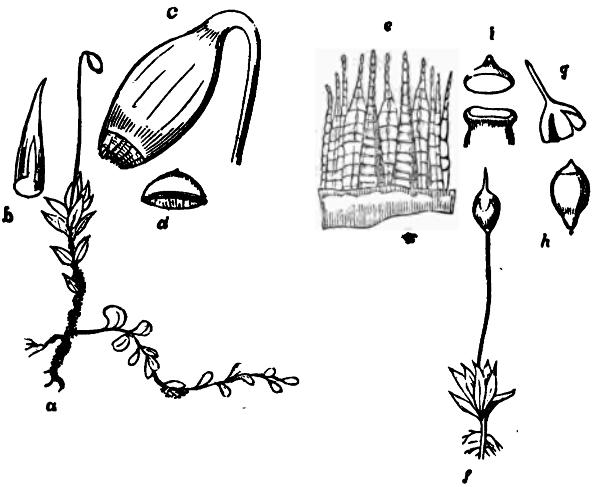
90. The sporangia are at first covered by a membranaceous body called a calyptra (καλύπτρα, a covering), and enveloped in the perichætial leaves in the axilla or summit of the branches. When first elevated above the perichætial leaves, nothing is apparent but a number of stiff bristle-like processes, each rising from its own perichæth. From this, however, we must except Dicranum undulatum, which has several setæ originating in the same perichæth, and the fruit of which appears in clusters. The young fruit of mosses is called, for this reason, setæ (*seta*, a bristle). As the setæ of mosses elongate, the reproductive cells at their summit begin to

swell and the sporangia to form. By the expansion of the sporangium, the calyptra which incloses it is separated, or rather torn from its base, and carried upwards on the apex of the sporangium. If, when this happens, the calyptra is torn away equally on all sides from the base of the sporangium, so as to hang over it vertically, the calyptra is said to be mitriform, or mitre-shaped. If, on the contrary, the rupture takes place unequally, by the adhesion of part of the membranaceous matter of the calyptra to the base of the sporangium, the sporangium, in swelling, necessarily splits up the calyptra on one side, so that when the adhesion is overcome the calyptra is ultimately carried up, and has an angular inclination to the surface of the sporangium; in this case, the calyptra is said to be cuculliform (*cucullum*, a hood). When the calyptra has fallen, the sporangium is seen to be inclosed by an operculum or lid, which assumes different shapes in different species, being convex, conical, or rostrate (*rostrum*, a beak). As fructification advances, the operculum or lid falls, and the peristome (*περί* around, *στομα* mouth) or mouth of the sporangium is revealed, which, in some species, presents to the eye the appearance of a beautiful fringe, the organization of which can only be distinguished by the microscope.

91. As an illustration of the parts already described, Fig. 29 is given, which is taken from Dr. Gray's *Botanical Text-Book.*

92. When the peristome of different species of mosses is examined, it is found to consist in some of an inner and outer peristome, which is, in fact, a peculiar organic modification of the inner and outer membrane of the sporangium.

Fig. 29.



a. Bryum cuspidatum in fruit, natural size. *b.* The cuculliform calyptra detached from the sporangium. *c.* Magnified sporangium, from which the operculum or lid (*d*) has been removed to show the peristome or mouth of the sporangium. *e.* A portion of the inner and outer peristome highly magnified. *f.* Physcomitrium pyriforme in fruit, showing the mitriform calyptra. *g.* The calyptra detached from the sporangium (*h*). *i.* The operculum or lid removed from the sporangium, showing it to be destitute of a peristome.

The outer peristome usually exhibits a number of broad, short, lanceolate processes called teeth, and the inner is developed into long filamentous ciliæ (*cilium*, an eyelash). Sometimes there is only one peristome or fringe, or the membrane, instead of being developed into teeth or ciliæ, may stretch across the mouth of the sporangium and close it altogether, as in the genus Atrichium; or, perhaps, neither of the membranes is developed, and the sporangium is without a peristome, as in the genus Physcomitrium.

93. The teeth of mosses are a beautiful object beneath the microscope, and follow a regular geometrical law in their numerical relations, being either four, or multiples of that simple number, 8, 16, 32, or 64; and from their absence, and differences in their number and degree of cohesion when present, the generic character of mosses is wholly taken.

94. The teeth of mosses are exceedingly hygrometrical, or easily affected by moisture. When the sun shines bright and warm, and the atmosphere is dry, the mosses on ten thousand rocks and hills expand and spread abroad their teeth, which may be seen then at right angles to the mouth of their sporangia; the sunlight pours down into the sporangia, and the young spores spėedily ripen under its influence. But when clouds shade the sun, and the air becomes surcharged with moisture, the teeth of the peristome immediately curve over the mouth of the sporangium, fitting together in the most beautiful manner, and effectually closing it, so that not one particle of moisture can enter the sporangia to injure the young spores. This beautiful mechanism may be seen in operation on the top of almost any stone wall, or on the surface of rocks, in the winter months, by those who will only search for it.

95. However philosophers may attempt to explain these movements on mechanical principles, and it is probable that, with the progress of science, all vital phenomena will be ultimately resolved into physical laws, yet have we not in these phenomena the first faint foreshadowings, as it were, of the powers of a higher vitality? Is there not manifest a shrinking away of the young life of mosses from what would

injure it, and do not mosses modify their organs to protect themselves? Let us look at the evident *design* of these movements. Surely the life thus manifested is only part of the system of life which pervades all organic matter, *the same in kind, but inferior only in degree.*

96. The pedicel or stalk of the sporangium, continued through the middle of the sporangium, forms a central cellular axis or support called the columella, around which the spores are agglomerated; enlarged under the sporangium, it forms an apophysis (ἀπόφυσις, excrescence).

97. The antheridia of mosses are produced like the capsules in the midst of little rosettes of leaves, which differ from those of the stem in appearance; they are minute, cylindrical, clavate, cellular sacs, which discharge from their apex a mucilaginous fluid containing numerous cellules, in each of which a spiral phytozoon (φύτον a plant, and ζῶον an animal) is seen. These exhibit active movements in water, at certain periods of their existence, similar to the zoospores of the algæ!! Here again the vegetable appears to approach the animal kingdom. Whilst the highest classes of animals and plants are widely separated from each other, the lowest members of each kingdom approximate so closely that it is impossible to draw a line of demarcation between them.

98. The antheridium-bearing plants of Polytrichium, or the common hair-cap moss, are very conspicuous, and are selected as most suitable for the purpose of illustration. In Fig. 30, at *a*, we have represented the antheridium-bearing plant of the Polytrichium. It will be seen that the leaves at the apex are different in form from those on the side of the

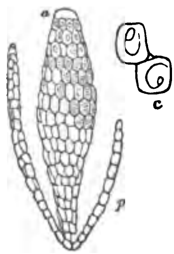
stem; this difference is owing to the peculiar functions assigned them. They surround the antheridia or male organs

Fig. 30.

a

of the plant, which are the analogues of stamen, together with certain cellular filamentous bodies called paraphyses (παράφυσις, an offset), which are considered to be abortive antheridia. Fig. 31 is a magnified view of an antheridium *a*, which is composed of quadrangular cells *c*, each of which

Fig. 31.



contains a phytozoon. Surrounding the perfect antheridium, there are abortive filaments or paraphyses *p*.

CHAPTER II.

VASCULARES, OR VASCULAR FLOWERLESS PLANTS.

99. Every plant germinating from the spore or seed has a tendency to develop in three directions, upwards, downwards, and horizontally, according to the nature of the tissues of which it is composed. The fibrous and vascular system is developed vertically, in an ascending and descending direction, excepting in the case of the leaves, where it takes a horizontal spread; the cellular system, on the contrary, is developed for the most part horizontally. In the lower tribes of cryptogamic plants, the structure is wholly cellular, and the plants, therefore, are wholly stemless and leafless, the greater part of them consisting of flat expansions of vegetation, spreading centrifugally in one plane, increasing by additions of cellular matter to their periphery or circumference, so as to form a thallus, or bed of vegetable matter; hence these plants have been called Thallophytes (θαλλος a frond, and φυτον a plant).

100. In the higher tribes of cryptogamic plants, the fibrous and vascular tissues enter into the composition of their structure, and these plants necessarily develop vertically as well as horizontally. These two systems of tissue, I mean the vascular and fibrous vertical system and the horizontal cellular system, cross each other at right angles, become interwoven with each other, and form a common axis of vegetation or stem. Part

of the vascular and fibrous tissues of the stem take an ascending direction, and associated with the horizontal cellular tissues forms the branches and leaves; the other part take a descending direction, and contribute to the formation of the roots and fibres in the soil.

101. It is true that in the mosses we have the higher type of vegetation fully realized. We have an ascending axis or stem clothed with symmetrically arranged leaves, and a descending axis or root, in these humble plants, although their structure is wholly cellular. It is not surprising, however, that in this instance the cellular system should take a vertical development, since we have shown that the vascular and fibrous vertical system is only a modification of the cellular. The cells of the sphagnums or bog-mosses contain spiral fibre, and woody fibre seems to be faintly foreshadowed in those elongated cells which form the nerves of the leaves of many mosses. Mosses, owing to their cellular structure, seldom rise more than a few inches above the ground. Not so with the

LYCOPODIACEÆ, OR CLUB-MOSSES.

102. In these plants we have a most decided advance in organic development. In their general appearance, they resemble mosses to which they are closely allied, although they are much larger; for, owing to the strength imparted by the bundles of woody fibre running lengthwise through their stem, they are enabled to rise to a greater elevation above the ground, some of them growing two or three feet high.

Fig. 32.

Lycopodium clavatum. *a.* Scale of a spike with a capsule (magnified).

103. The genus Lycopodium (Fig. 32), which forms the type of this little family, appears to occupy an intermediate position between the Ferns and the Mosses, and in some respects seems to be allied to the Coniferæ.

104. It is in these plants that vascular tissue first makes its appearance in the form of woody and annular vessels, which form a bundle in the centre of the stem, and which is encompassed with cellular tissue; from this vascular central axis smaller bundles of woody tissue communicate with the imbricated subulated leaves, which have an epidermis pierced with true stomates, and are disposed spirally about the stem.

105. The roots are still of a secondary character, that is,

they spring from all parts of the stem in contact with the earth, and are not confined to one of its extremities.

106. The reproductive capsules are situated in the axils of the metamorphosed leaves of the stem, which form long, yellow, clavate spikes in Lycopodium clavatum; whilst, in other species, as in Lycopodium lucidulum, these leaves retain their usual green color and appearance, being apparently unaffected physiologically, by being in the immediate neighborhood of the fruit.

107. These plants abound in warm, moist, insular climates, and are especially interesting as being allied especially to the fossil plants called Lepidodendrons. The Lepidodendrons are very abundant in most English coal-mines, where some have been found nearly entire from their roots to their upper branches, one specimen being forty feet high and thirteen feet in circumference. These fossil plants are called Lepidodendrons, or scaly trees, because their cylindrical stems are covered with marks left by the fallen leaves. In their structure, they accord with the Lycopodiums; they are, in fact, gigantic club-mosses.

108. The Lycopodium squamatum, of Brazil, exhibits a very interesting case of locomotive power. This plant, when deprived of water during the dry season, unroots itself from the ground, rolls itself into a ball, and becoming withered, and apparently devoid of life, is driven hither and thither by the wind, until it reaches a moist situation, when it speedily unrolls itself, sends down its roots into the soil, and spreads out its leaves, which from a dingy brown speedily change to the bright green hue of active vegetation.

FILICES, OR FERNS.

109. The Ferns are the most highly developed of the Cryptogamia, or flowerless plants. The higher representatives of the family possess roots, conspicuous stems and leaves, whilst almost every kind of vascular tissue enters into their composition.

110. We give the name of *frond* (*frons*, a bough) to the foliaceous appendages of the stem of ferns, because they appear more analogous to branches enlarged into leaves (as for example to the foliaceous and flattened branches of Phyllanthus amongst flowering-plants), than to leaves, properly speaking.

111. The lower representatives of the family of ferns are found in Europe and in all temperate climates, and are developed as perennial, herbaceous plants, from a rhizome or prostrate stem, which either creeps horizontally along the ground, or burrows beneath its surface the fronds which it produces, annually perishing, without producing an elevated trunk. These herbaceous ferns seldom rise more than three or four feet above the ground. They prefer moist, shady situations, and are found overhanging the margin of streams and rivulets, or springing from the crevices of rocks which they cover and adorn with their bright green feathery fronds.

112. A considerable degree of heat as well as humidity appears to be requisite to the complete development of ferns. Beneath the warm bright sun of the tropics, they attain the noblest arborescent forms. The united and persistent basis of the decayed and fallen fronds forms an aerial stem, which

sometimes attains an altitude of from 50 to 60 feet above the earth's surface, crowned at its summit by a magnificent bouquet of gigantic fronds finely and elegantly divided. Fig. 33

Fig. 33.

represents the Alsophila armata, a tree-fern of Brazil.* As the lower fronds decay and drop off, the young upper fronds gradually unroll and become pendent, and in this manner continual additions are made to the height of the stem, and the growing point is carried upwards, the stem increasing in altitude, but not in diameter.

113. It is for this reason that these plants are called Acrogens (ἄκρος a summit, and γεννάειν to produce) or summit-growers, because they increase by additions of cellular and vascular matter to their extremities, and have no provisions for any subsequent increase in diameter.

114. Ferns, in their infancy, resemble the adult liverworts, having a green, flat, pro-embryo like the thallus of the frondose liverworts. This pro-embryo or pro-thallus afterwards gives rise to the proper stem and frond of the fern. In Fig. 34, *s* is

Fig. 34.

the spore of a fern, the Pteris longifolia, sprouting and giving off a rootlike process *r*, and a flat cellular expansion *p*, called the pro-thallus or pro-embryo. It is on this expansion that the antheridia and pistillidia occur, and the former having fulfilled

* Richard's "Précis de Botanique," pt. i., Paris, 1852.

their function, the latter develop into the frond. These bodies are, therefore, only found on these plants whilst in a young and nascent state; in the mosses, on the contrary, antheridia and pistillidia are found on the fully developed plant.

115. The fronds of the different species of ferns are circinate, or rolled up from the apex to the base in the bud, in a beautiful spiral. This disposition of the plant is analogous to that of the Droseraceæ and Cycadaceæ amongst flowering-plants. Ophioglossum vulgare is, however, an exception, as the fronds are straight, and never rolled up or circinate in the bud.

116. The young unrolled fronds are copiously covered with membranaceous, chaffy scales, but, as the heat and light of the sun increase, the scales fall off, and the fronds gradually unroll, until at length their entire surface is spread abroad in the atmosphere.

117. After the vegetative functions of the plant have been exercised for a certain length of time, and the frond has acquired its maximum growth, certain parenchymatous cells situated along the margin or on the under surface of the frond begin to manifest their reproductive functions. These cells develop into regular organized bodies called *thecæ* (θεκη, a repository), which contain the spores or reproductive matter. The thecæ invariably spring in clusters from the nerves or veins of the frond. The spores are ordinarily very small, and are free in the interior of the thecæ at every epoch of their development.

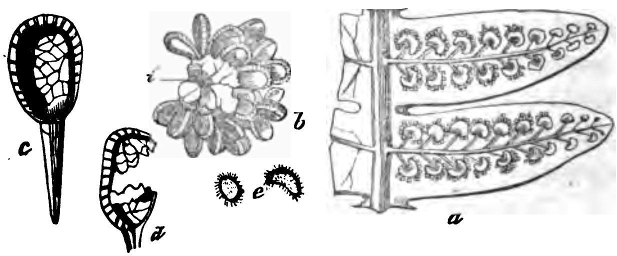
118. The clusters of thecæ are called, botanically, *sori* (*sorus*, a heap), presenting to the naked eye the appearance of circular or oblong masses, or heaps of powder. This pulverulent

appearance only shows itself in the more advanced stages of development, the thecæ being at first concealed by the cuticle, which they raise up like a blister, and ultimately rupture and detach from the parenchyma of the frond in a variety of ways, which serve as characteristics of the genera. It is necessary, however, to except Polypodium vulgare, or the common polypody, the thecæ of which are formed above the cuticle.

119. The cuticle which is thus ruptured from the frond is called the indusium. Generic and specific characters depending on the peculiarities of its form, and the nature of its rupture from the parenchyma of the frond, can only be detected in early spring. Later in the season, the indusium withers away, and the sori or heaps of thecæ are alone visible.

120. In Fig. 35,* at *a*, we have represented two of the pin-

Fig. 35.



næ of Polypodium thelypteris covered with sori, having an indusium; *b* is a magnified view of one of these sori, showing the clusters of annulate thecæ and the partially withered

* Richard's "Précis de Botanique," pt. ii., Paris, 1852.

indusium *i*; *c* one of the thecæ taken from the cluster, and more highly magnified. It consists of a flattened bag of cellular tissue, which is partially surrounded by an elastic ring of cells, *annulus*, having a special structure. The walls of the cells of the annulus are much thicker than the walls of the cells which they surround; and, as the annulus has a continual tendency to straighten itself, when the theca becomes dry and the spores matured, it is suddenly torn open by the elastic straightening of the annulus, as shown at *d*, and the spores *e*, contained in its cavity, scattered. This beautiful contrivance of nature may be seen in operation in the ripened sori situated on the back of any dorsiferous fern.

121. The thecæ attached to the frond beneath the indusium appear to produce all the peculiarities of its rupture, by their different modes of development. In Polystichum acrostichoides, the marginal thecæ of each sorus are the first to develop, and the indusium is thus ruptured from the parenchyma and the epidermis, all round the margin, whilst it remains attached to the frond by its centre. In Woodsia, on the contrary, the central thecæ of the sori are the first to develop and effect a corresponding rupture in the cuticle, for the indusium is ruptured at its centre and forms a sort of cup-shaped involucre around the thecæ, being continuous with the epidermis of the frond at the margin. Sometimes the indusium is a mere fold of the margin of the frond, as in Pteris and Adiantum.

122. We stated that the thecæ or spore-cases of ferns were developed from the parenchyma of the frond. In some genera, the sori, or clusters of thecæ, are developed at the expense of

the parenchyma, the whole of which disappears, leaving nothing but the naked nerves all covered with sori. A striking instance of this kind is not uncommon in bogs in the form of a plant called the Osmunda spectabilis, or flowering-fern. The lower pinnæ of this fern present the usual leaf-like appearance, whilst the upper are entirely changed into sori.

123. The morphological changes of the frond into sori are well seen in Osmunda Claytonia. Some two to five pairs of the middle pinnæ of the frond of this fern are usually metamorphosed into sori. An occasional specimen may be found bearing pinnæ, in which the metamorphosis has been only partially effected, the pinnæ being partly parenchymatous and partly soriferous. In such specimens, nature herself teaches us her own process.

124. When the sori are moderately dispersed over the under surface of the frond; or, when developed in great numbers, if they are confined to its under surface; or, when only a part of the frond is metamorphosed into sori, then the same frond can still continue to exercise the functions of vegetation as well as of reproduction; but this ceases to be the case when the whole frond is metamorphosed into sori. Other fronds are then developed from the same rhizome to carry on the vegetative functions, which are barren and without sori, as we see exemplified in the barren and fertile fronds of Osmund cinnamomea, and Onoclea sensibilis.

EQUISETACEÆ, OR JOINTED FERNS.

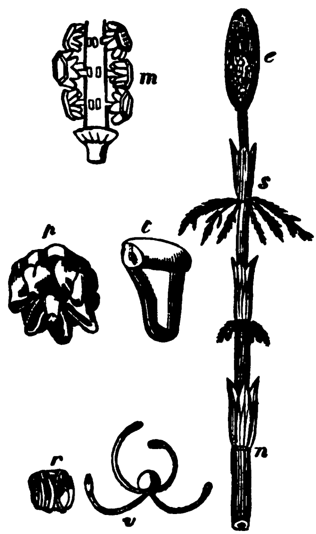
125. This family of plants is remarkably different from all the other Cryptogamia. It differs from the rhizomatous ferns in the structure of its stem and that of its reproductive

organs, and in sending up erect branches instead of leaves from the rhizoma. Dr. Lindley has placed this family near the Coniferæ, in the class Gymnospermæ, on account of the analogy subsisting between their reproductive organs and those of the coniferæ; but they are so totally different from the coniferæ in every other respect that this classification is somewhat objectionable, and has not been generally adopted, so that they still retain that place which Linnæus assigned them amongst cryptogamous plants.

126. The stems of these plants are cylindrical, simple, or branched, as in Equisetum sylvaticum (Fig. 36), striated longitudinally, tubular, and articulated; the cavity of the stem being closed at the articulations or joints, which are readily separable and surrounded by a membranaceous-toothed sheath *s*. The stems are, in this respect, somewhat analogous in organization to those of the grasses which are solid at the nodes (*nodus*, a knot), or joints, and tubular between the internodes; but they are without leaves, as we are unable to consider as such the membranaceous sheaths which surround their nodes *n*, or articulations *above* the verticillate branches; for the branches should be developed between the sheath and the stem, if the sheath were a circle of abortive and united leaves, whereas the sheath is, in reality, situated in the axilla of the branches, and appears to be only the termination of the external portion of the stem, the continuity of which is broken by the formation of the nodes or articulations. The whorls of branches at the nodes are jointed, striated, and tubular, being solid and sheathed at the joints, like the stem from which they spring.

127. The organs of fructification consist of an ovate or more or less elongated spike composed of thick peltate, pedicellate, polygonal scales, very similar to those of the male flowers of the Taxus baccata, or common yew-tree, each scale having several thecæ or sporangia attached to its lower surface longitudinally dehiscent, and discharging a multitude of little bodies termed spores, each of which is embraced by four hygrometrical clavate filaments called elaters, by which the mechanical dispersion of the spore is effected. In Fig. 36

Fig. 36.



we have represented the summit of the stem of Equisetum sylvaticum (Dr. Gray's *Botanical Text-Book*); *e* shows the cone of fructification; *m* is a magnified view of part of this cone, exhibiting the peltate polygonal fructification. One of

these organs is more highly magnified at *p*, and exhibited so as to show the attachment of the thecæ to its lower surface; *t*, a separate theca, still more magnified; *r* and *v* are the spores, with the clavate filaments, which are shown rolled in a spiral around the spore *r*, and spread out from the spore *v*.

128. Struck by the analogy of form which exists between the reproductive organs of the Equisetaceæ and the stamens of some Coniferæ, Linnæus named these clavate filaments stamens, without indicating those which he regarded as pistils. Hedwig, on the contrary, considered these bodies as hermaphrodite flowers, the globular part being the pistil and the filaments the stamens, the pollen being situated on their exterior surface. But these filaments are certainly analogous to the elaters of Jungermannia. These spores are first formed in the interior of the cells, the walls of which, in place of being absorbed, remain attached to the spores in the form of elaters.

129. When moist, these filaments are twisted spirally around the central spore; but, when dry, they unroll and expand elastically, thus moving the spore along with them in various directions. If a spike of the Equisetum, when ripe, be shaken over white paper, the spores will appear like brown powder on its surface; and if we gently breathe on them, and examine them at the same time with a magnifier, they will be seen crawling about the paper like so many little spiders. This circumstance arises from the hygrometric property of the elaters which are affixed to the spores and possess this property in order to effect their dissemination.

130. All the species of Equisetaceæ are, with us, perennial

herbaceous plants, growing in moist places, with stems about half an inch in diameter and two feet high, which is increased to a maximum of twelve feet in equinoctial marshes, and are remarkable for the quantity of silex which enters into their composition. The equisetum is well known under the name of horse-tail.

131. The cellular Cryptogamia are seldom met with in a fossilized condition. One or two instances are mentioned of mosses being found fossil in the upper and tertiary deposits only; but there is a general paucity of plants of this character, whilst on the other hand there is a decided preponderance of ferns and of the higher orders of the cryptogamia.

132. Fossil Equisetaceæ abound in the coal-measures and in strata far more ancient; indeed, they appear to belong to the earliest terrestrial flora of which any traces remain. Some of them attained an enormous size, being from one to three feet in diameter, and from thirty to forty feet high. In most instances when these plants are found, their stems are pressed flat, but specimens have been met with in a vertical position, and retaining their cylindrical character.

133. Fossil Ferns seldom exhibit any traces of fructification, and are chiefly distinguished by the shape and forked venation of their fronds. About one hundred and fifty species of fossil ferns have been detected in the carboniferous strata in England alone. The originals of many of these species were undoubtedly arborescent. Fossil fern-stems are rarely found, yet a few have been discovered bearing all those characteristic marks by which the tropical arborescent fern-stems are distinguished. Cicatrices, or scars, are left by the fallen fronds

on the stem of tree-ferns, and these cicatrices are very conspicuous in the fossil fern-stems, and form a valuable and accurate indication of their true character.

134. *Certain conditions necessarily produce certain phenomena.* This philosophical axiom is especially applicable to the phenomena of vegetation. Certain plants require certain conditions of temperature, air, light, and moisture, in order to insure their development from the spore or seed. But these fossil arborescent ferns and Equisetaceæ, although analogous in their growth to the existing arborescent species in tropical countries, are altogether specifically different. They have had their final development, and are now extinct. The earth, once their home, is now their sepulchre. Hence it is evident that the conditions under which they were developed exist no longer; and when, along with these extinct plants, we find the remains of animals equally low in the scale of organization, and which have no living representatives in the zoology of any country, we have indubitable evidence of a system of organic change, which has been probably contemporaneous with the changes which have undoubtedly taken place in inorganic nature.

135. The history of the earth has been written by the Author of nature in characters the most striking and impressive, in its strata, which have been justly termed the "leaves of the stone book." But these characters can only be interpreted by a careful and accurate study of the living creation, and the existing laws which govern inorganic matter. Not only every world in space, but every atom in the universe, moves according to fixed and unchanging laws, and the inte-

resting facts revealed by geologists prove that the mutable and perpetually changing system of wonders by which we are surrounded is under the control of a sublime and mysterious Providence.

136. We have seen that every plant which consists of more than one cell or of a series of cells, which are *permanently* united together, may be divided into two distinct parts, to which the functions of nutrition and reproduction are respectively assigned (54). In like manner, all the organs which compose the structure of the most highly organized vegetation concur in the exercise of either one or other of these functions. In the compound organs of plants, we have additional complexity of structure, but no essential change of plan. The same distinction may be made of them into organs of vegetation and reproduction.

137. In the lower orders of the cryptogamia or flowerless plants, the organic parts which concur in the exercise of these functions are reduced to the utmost degree of structural simplicity, being at first confined to a single cell, as exemplified in the Protococcus, and certain confervoid plants (51), in which the union of the plant-cells is but temporary. But, as we advance in the scale of vegetable organization, we find these plant-cells remaining permanently united to each other, and developing into filamentous or foliaceous expansions, and finally into distinct organic parts, designated as root, stem, and leaves: so also the reproductive matter is at first confined to the same vegetative cell, then concentrated in certain specialized cells as in the bread-mould, and finally contained in regular

organs named *apothecia* in the lichens, *urns* or *capsules* in the mosses, and *thecæ* in the ferns.

138. The recent discovery, within the last few years, of antheridia or organized bodies, analogous to the stamens or male sexual organs in the flowering-plants, in the different tribes of the Cryptogamia, proves that these organized receptacles of the spores are produced by a similar process of fecundation, and hence they have been very properly termed pistillidia. Like the pistils or female organs of flowering-plants, they contain within their cavities fecundated germs or spores, which have equally the power as well as the highly elaborated seed of developing themselves into new cells, conformably to the arrangement of the cells of the plants in which they originated, and thus of continuing the same vegetable form in the earth.

139. This discovery of the analogues of sexual organs in the cryptogamia (χςυπτος concealed, and γάμος union or marriage) renders the term, as formerly understood, inapplicable to the present state of science. There is now no longer any doubt as to the existence of these organs. The only difference between the antheridia and pistillidia of Cryptogamous plants or flowerless plants, and the stamens and pistils of the Phanerogamous (φανεςός conspicuous, and γαμος union or marriage), or flowering-plants, is in the degree of their development, the stamens and pistils of flowers being antheridia and pistillidia in a more highly developed condition, and the same remark applies to the seeds or embryos which are contained in the cavity of the germen; these are

probably only spores which have arrived at a higher degree of development.

140. We have seen how beautifully nature has simplified the laws of vegetation and reproduction, in the lower tribes of the Cryptogamia or flowerless plants; these plants afford us the best facilities for investigating questions of anatomical structure, and showing us what is really essential to vegetation and reproduction. At some future time, we may call attention to the manner in which the same laws are expressed in the higher series of the Phænogamous or flowering-plants, as the beauty and simplicity of these laws will be more readily appreciated and understood, and can only be fully revealed by the study of the manifold varieties of form assumed by the vegetative and nutritive organs of plants, in the completed type of vegetation.